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(54) Abstract Title
Cyclone separator

(57) A three stage cyclone separator suitable for use in a domestic vacuum cleaner comprises a first stage (13, fig 9) wherein the fluid enters tangentially (11, fig 9) and the lighter phase leaves axially in the first direction (41, fig 9), whilst the heavier particles exit axially in the second direction towards a collection bin (31, fig 9) which is partially separated from the first stage by a flange (21, fig 9) which hinders heavy particles form being re-entrained in the fluid flow. Fluid leaving the first stage moves axially through a second stage (54, fig 9) to the third stage. In the third stage, the fluid enters tangentially (71, fig 9) and the heavier particles move axially into a collecting region (33, fig 9). This collecting region is an integral part of the separation chamber and as such a vortex is established therein which holds the heavier particles to the circumferential wall and prevents them from being re-entrained into the clean air which leaves the third stage axially (74, fig 9) and passes once again through the second stage on its way to the final exit (63, fig 9).

Triple Vortex with Parallel Stage 3 and Baffle

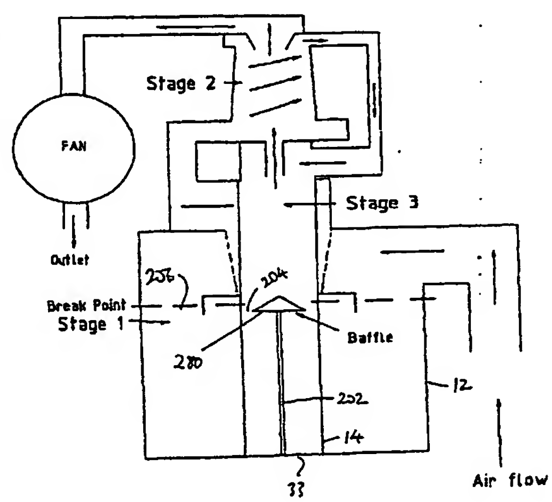

Fig. 10

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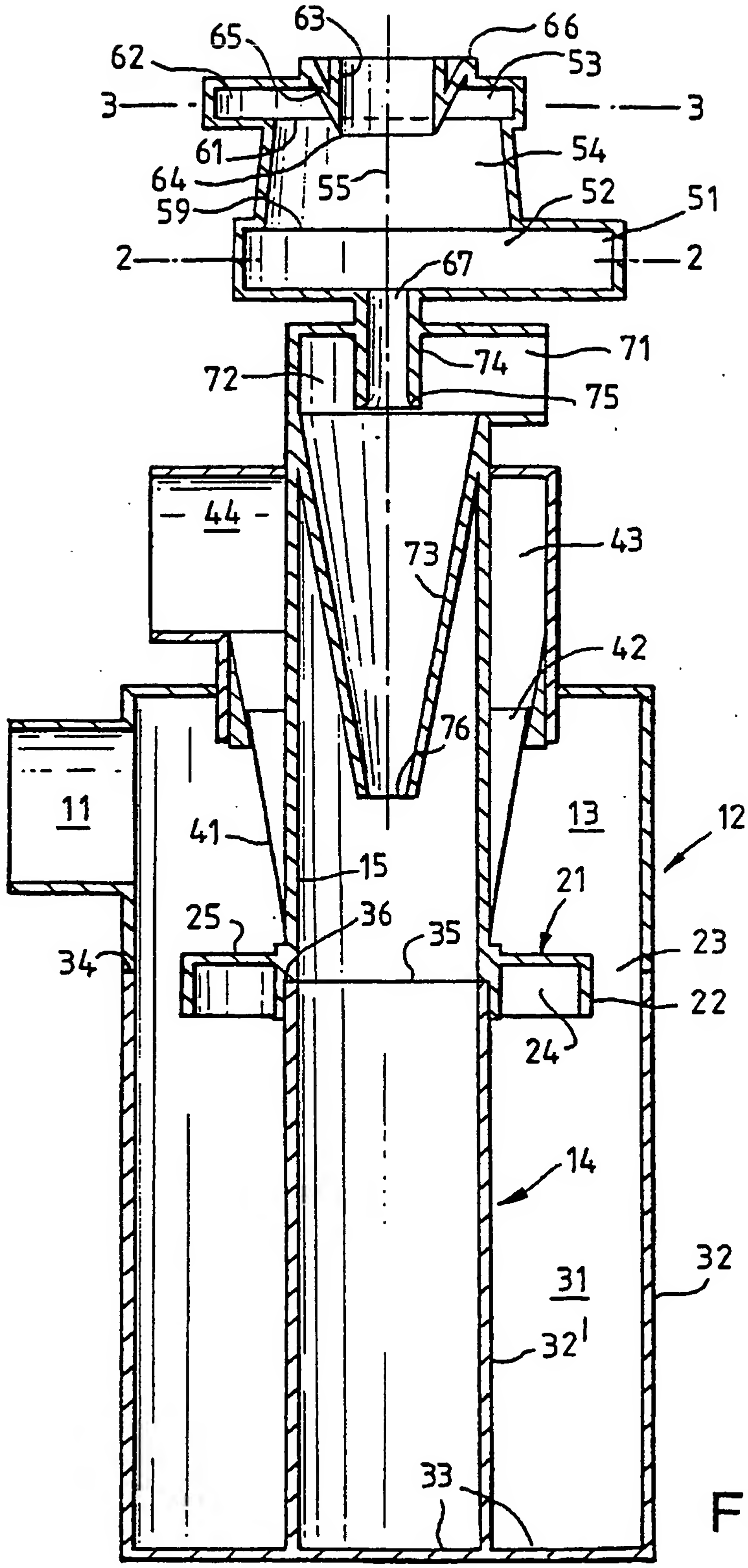

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Fig. 1

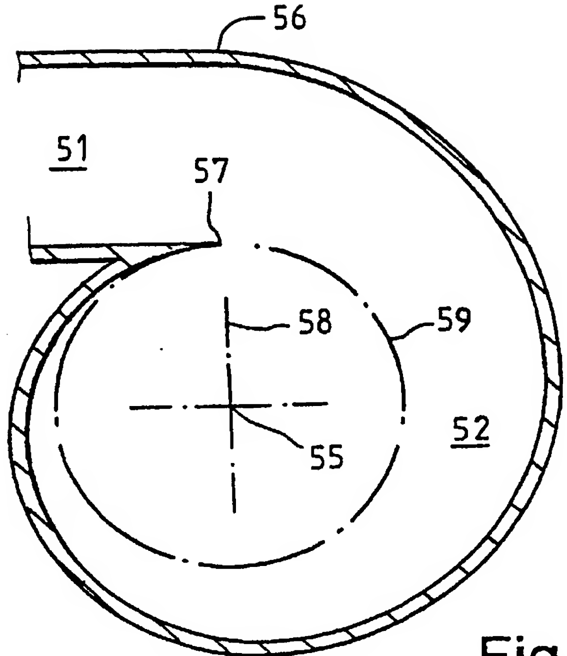

Fig. 2

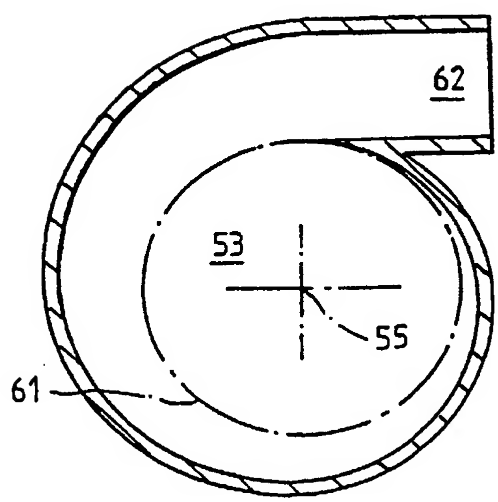

Fig. 3

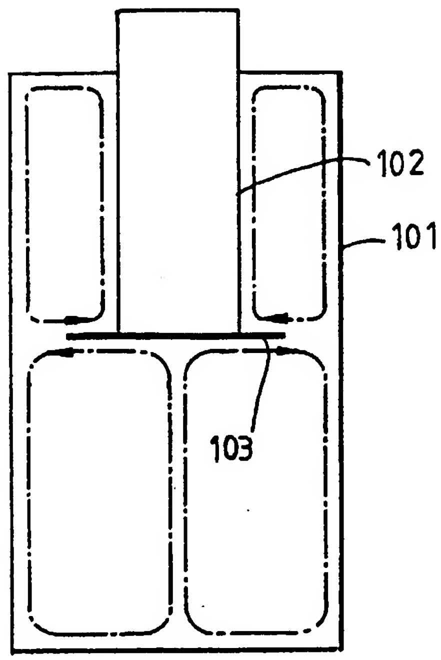

Fig. 4

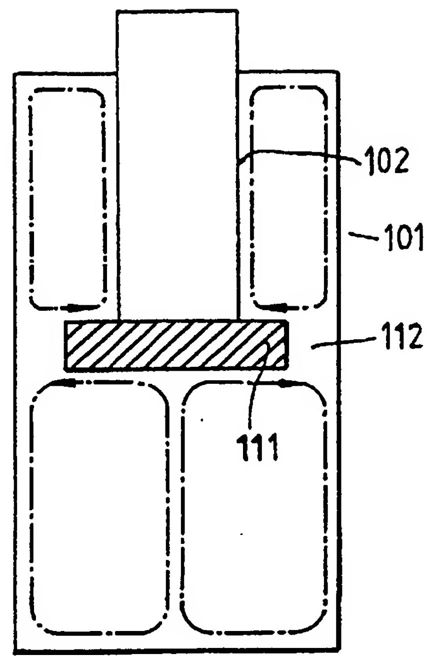

Fig. 5

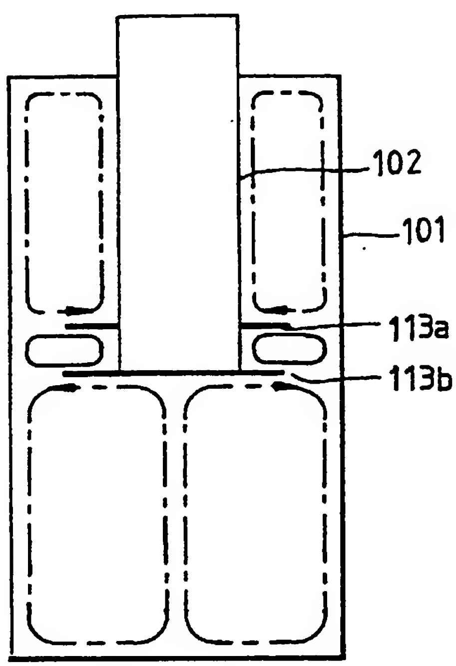

Fig. 6

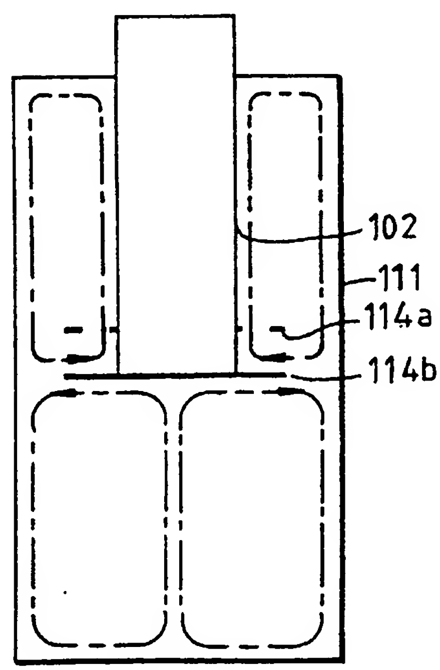

Fig. 7

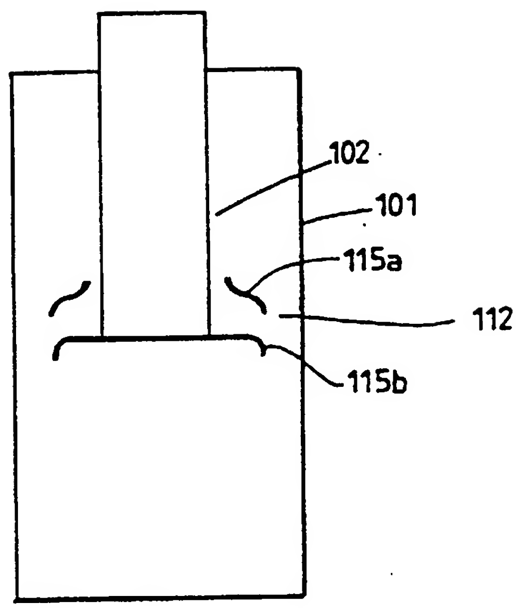

Fig. 8

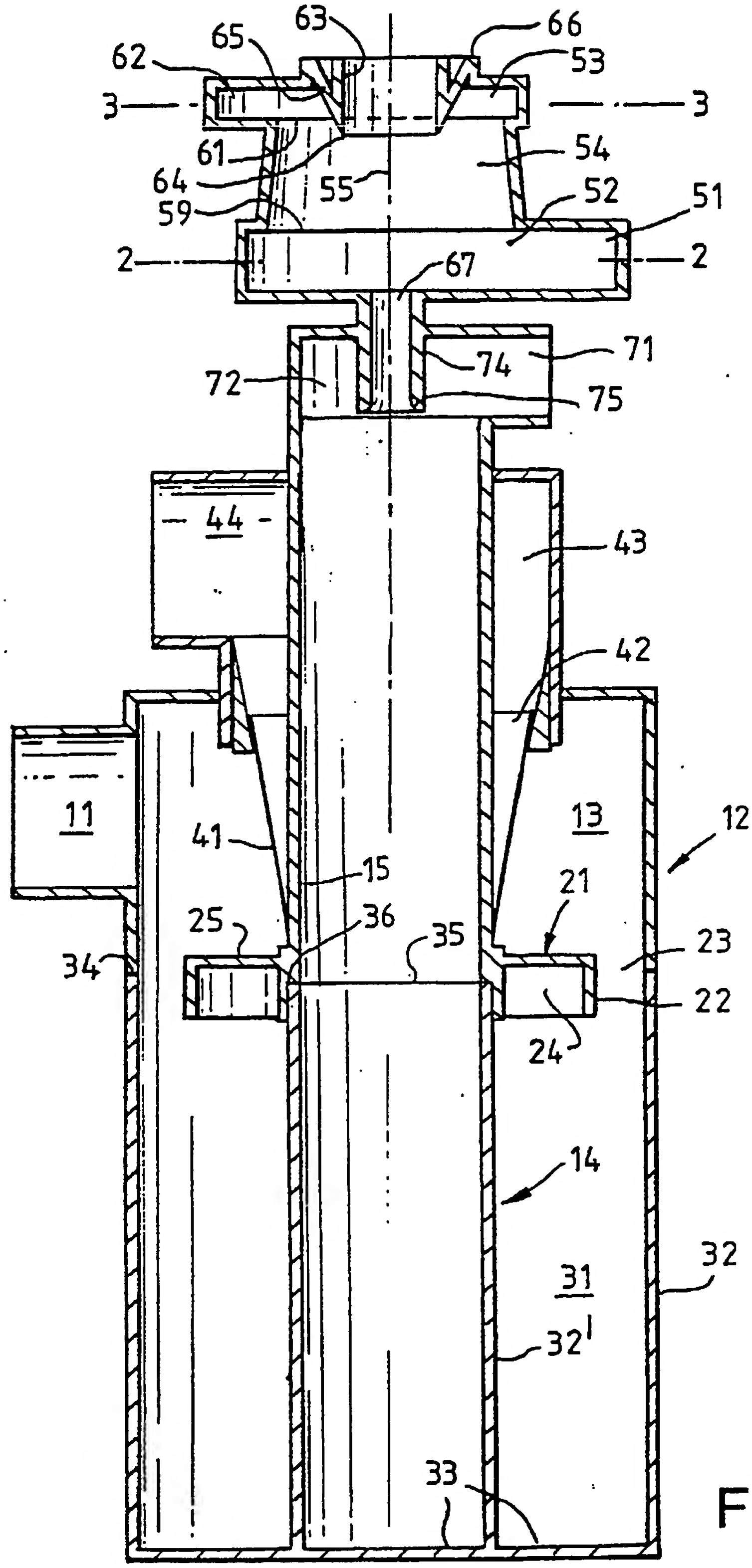
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Fig. 9

Fig. Triple Vortex with Parallel Stage 3 and Baffle

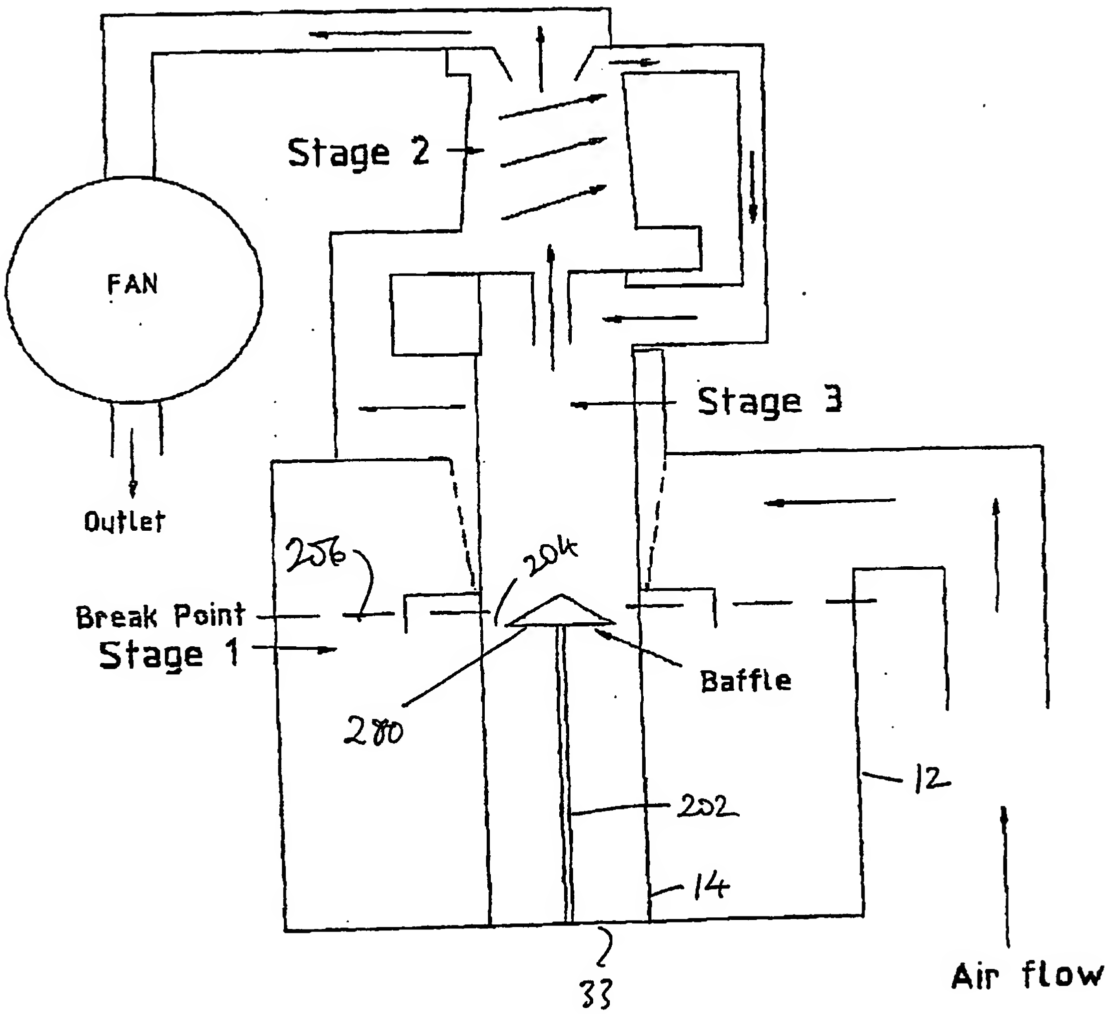

Fig. 10

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CYCLONE SEPARATOR

This invention relates to the separation of fluid phases, for example the separation of particulate matter from gases such as air.

Standard cyclone separators cause the incoming fluid mixture to swirl around a chamber so that phases separate radially due to the accelerations towards the axis, the separated phases being removed through separate outlets at different radii. Besides the chamber in which separation takes place, an inlet chamber may be provided in which linear motion of the fluid mixture is converted into swirling motion. This has normally been arranged by making the inlet chamber a cylinder with a linear inlet conduit entering the periphery of the cylinder along a tangent, so that the fluid from the inlet conduit then swirls about the cylinder axis.

Patent number GB 2330786 describes an apparatus where the fluid mixture to be separated into phases is introduced into the apparatus illustrated in Figure 1 by a tangential conduit 11 leading to a cylindrical separation chamber 13 at the top of a cylindrical container 12. Within the container is a co-axial inner cylinder 14 extending through the full height of the container 12.

The separation chamber 13 is defined at its lower end by a baffle 21 extending outwards from the inner cylinder to a peripheral wall 22 which baffle defines with the wall of the container 12 an annular gap 23 whose (radial) width is slightly less than the (axial) length of the peripheral wall. In this particular example the width is just under 75% of the length. The baffle 21 is undercut at its lower side 24, but presents a continuous upper plane surface 25 and the wall 22 is a continuous outer cylindrical surface. Possible variations of the baffle are described in the simultaneously filed international application based on GB

9723341.5 and 9819071.5, and features from the statements of invention in that application may be combined with the separator of the apparatus herein described. Furthermore, features from the statements of invention in the simultaneously filed international application based on GB 9723342.3 and 9817074.9 may be combined with the separator of the apparatus herein described.

Below the baffle 21 the container 12 defines with the inner cylinder 14 an annular collection chamber 31 to which the only access in the assembled state of the apparatus is through the gap 23. The apparatus can be disassembled by removing the lower portions 32, 32' of the two cylinders which are formed as a single unit joined by a common base 33. The cylindrical container 12 splits at a level 34 just below the top of the baffle and the inner cylinder 14 splits at a slightly lower level 35, still within the length of the baffle, and its upper end fits within a recess 36 in the upper part 15 of the inner cylinder 14 within the baffle. The split in the cylindrical container is shown as a butt join, but some means of making the join more fluid-tight may be provided. A bayonet fitting may be provided to join the cylinders at their split planes; external clamps are another suitable joining means. Annular closed cell foam seals (not shown) may be provided to make the joins fluid-tight.

Above the baffle 21 the central cylinder is surrounded by a frusto conical perforated shroud 41, tapering outwardly towards the top of the container 12 and defining the inner boundary of the separation chamber. The volume between the shroud and the inner cylinder provides an outlet duct 42 which continues to taper outwardly above the shroud and then becomes cylindrical at 43.

The apparatus so far described forms the first stage of the separator. Fluid mixture flowing in the tangential conduit 11 is caused to swirl around the separation chamber 13 as

it enters that chamber, the lighter phases tending to move to the smaller radii and heavier phases to the greater radii where they will diffuse and fall under gravity through the gap 23 to the collection chamber 31. As discussed in the co-pending application, the proportions and dimensions of the gap 23 are chosen so that sufficient heavier phase fluid passes through the gap and very little of the heavier phase fluid in the collection chamber 31 is drawn back through the gap. The provision of one or more annular co-axial baffles (not shown) on the base 33 assist the retention of heavier phases against re-entrainment. The lighter phases remaining in the separation chamber 13 pass through the shroud 41 and continue to swirl around the upper part 15 of the central cylinder 14 in the outlet duct 42, 43. This first stage of the separator is an initial stage, in which efficiency is not of prime importance. In a vacuum cleaner application, it serves to remove the fluff and heavier dirt particles from the flow. The shape of the separation chamber and the relationship of its inlet are not critical. The critical separation occurs in the later stages to those described below.

The cylindrical part 43 of the outlet duct 42 of the first stage has a tangential outlet 44 leading by means not shown to the inlet conduit 51 of a second stage which has involute shaped inlet and outlet chambers 52, 53 with an intermediate chamber 54 which joins the inlet and outlet chambers along the common axis 55 of the three chambers. As can be seen from Figure 2, the curved wall of the inlet chamber decreases from a maximum radius at 56 to a minimum radius at 57 as it subtends the full 360 degrees around the axis 55. The downstream end of the inlet conduit 51 is defined on the outside 56 by the curved wall of maximum radius and on the inside 57 by the curved wall of minimum radius. For ease of manufacture, the radius decreases gradually, the curved wall having at least three, and in this embodiment four, sections of constant radius and subtending equal angles (90 degrees) at their respective

centres, adjacent sections being centred about points on the common normal to the adjacent ends of those portions (thus making those common ends tangential), the radii of successive sections increasing from the minimum to the maximum. In this embodiment, the innermost section of the involute is centred on the normal 58 which passes through the axis 55. The radius of the inlet end 59 of the intermediate chamber 54 is not greater than the minimum radius of the inlet involute and in this embodiment is smaller than the smallest of the four radii.

The intermediate chamber 54 is frusto-conical, tapering inwardly to a smaller radius at its outlet end 61 which is in this embodiment is smaller than the minimum radius of the outlet involute. The radius of the intermediate chamber 54 is of course smaller than the minimum radius of the inlet involute. The curved wall of the outlet involute gradually increases in radius in subtending the full 360 degrees leading to an outlet conduit 62 for heavier phases in the opposite manner to that described for the inlet involute, the involutes being arranged to receive fluids swirling in the same sense about the stage axis 55 as the swirl induced in the inlet involute. There is an axial outlet from the second stage comprising a co-axial inner cylinder 63 extending through the outlet chamber and protruding at 64 slightly into the intermediate chamber 54. A frusto-conical wall 65 surrounds the inner cylinder, tapering outwards from the entry of the axial outlet to the far end 66 of the outlet involute. The inlet involute chamber 52 has an axial inlet 67 of radius small compared to all the radii of the chambers, in this example being one quarter of the minimum radius of the inlet involute.

The fluid mixture flowing in the inlet conduit 51 of the second stage follows the increasing curvature of the curved wall of the inlet involute and so swirls around the axis 55 with increasing velocity. As the swirling mixture travels along the axis 55, the heavier phases tend to move to the

outer radii and the lighter phases tend to move towards the axis of the stage. The velocity of swirl is increased by the small entry radius of the intermediate chamber and further by its taper. The lighter phases near the axis will therefore leave the intermediate chamber through the axial outlet cylinder 63, whereas those phases at greater radii will be urged by the tapered shield 65 into the outlet involute around the curved wall of which they will swirl towards the outlet conduit 62. The swirling fluids in the inlet involute will create a low pressure point therein on the axis 55, so that fluids presented at the axial inlet 67 will tend to be drawn into this stage of the separator to move along the stage axis, as will be described later.

The outlet conduit 62 of the second stage is connected by means not shown to an inlet conduit 71 which is tangential to the cylindrical inlet chamber 72 of a third stage. The inlet chamber opens on one side into a co-axial frusto-conical chamber 73 which tapers from a maximum radius equal to that of the inlet chamber 72 to a minimum at the other end where there is an axial outlet 76 for heavier phases, located within the upper part 15 of the inner cylinder of the first stage at a level within the shroud 41. A cylindrical duct 74 coaxial with the inlet chamber 72 has a mouth at the one side of the inlet chamber formed with a radiused inner rim 75 and extends therefrom through that chamber 72 to connect with the axial inlet 67 of the second stage, the axes of the three stages being in this embodiment coincident at 55 and vertical, the outlet 76 of the frusto-conical chamber 73 being at the lowest point of the third stage.

Fluid mixture flowing in the inlet conduit 71 of the third stage is caused to swirl around the chamber 72 as it is deflected around its curved wall, thus providing further separation of the phases. The lighter phases tend to move towards the axis 55 where they reverse axial direction and

enter the inner cylinder 74 and are drawn back into the axial inlet 67 of the second stage by the reduced pressure on the axis of the inlet chamber 52 of that second stage, thus being re-subjected to the separation processes of the second and third stages. The flow which is recirculated from outlet 62 back through the inlet 71 is about 5 to 30% of the flow which exits through the outlet 63. By recirculating this fraction, it is possible to form the third stage much smaller in volume than if the third stage had to deal with the whole flow through the second stage. The location of the inner cylinder 74 within the inlet chamber 72 provides a vortex finder as this third stage of the separator. The heavier phases in the chamber 72 tend to move to greater radii within the frusto-conical chamber 73 as they continue to swirl, moving down the tapering wall towards the lower end of that chamber to leave by the outlet 76 at the lower end, to continue to the base 33 of the inner cylinder 14 of the first stage.

Heavier phases from the first and third stages therefore collect at the base 33 of the first stage container, those from the first stage within the annular chamber 31 and those from the third stage within the chamber within cylinder 32'. Both these chambers can be emptied by splitting the container as described above. Since there is only a small overlap between the portions of the container 12 across the split, the removal can be effected easily without knocking the upper portion which knocking might cause heavier phases such as dust to be dislodged, falling when the lower portion is no longer in place to collect them.

In the embodiments so far described, the apparatus is a vacuum cleaner and the mixture of fluid phases comprises dust particles entrained in air. Other mixtures which could be separated include silt entrained in a liquid or a mixture of oil and water. Gases, liquids or solids of different density, or any combinations thereof, or gas that

is dissolved in liquid can be supplied to the inlet chamber.

It may be helpful to understand the operation of the barrier/baffle/flange to consider Figure 4 in which a cylindrical container 101 contains an inner cylinder 102 having a flange 103 extending outwardly for about half the distance to the wall of the container 101. In this arrangement the inner cylinder extends throughout the region above the flange, but does not extend below it. There is therefore an annular compartment above the flange and a cylindrical compartment below it.

The fluid-based mixture is introduced into the annular chamber of the container 101 with a swirling motion carried by the involute shape of the duct leading into the container so that the mixture rotates around the inner cylinder 102. Heavier components in the mixture tend to move to the outer regions of the cylindrical container 101 due to the swirling motion and tend to separate out and move by diffusion and under gravity passing the flange 103 to enter the cylindrical compartment and come to rest on the bottom of the container 101. The lighter components remain in the annular compartment which they leave by means not shown in this Figure.

The swirling primary flow generates secondary flows. Figure 4 shows by dotted closed curves the secondary flow patterns in the fluid mixture. Above the flange 103, the flow tends to be downwards at the outer region of the cylindrical container 101 and upwards close to the wall of the inner cylinder 102 so that immediately above the flange 103 the flow tends to be radially inwards. Below the flange 103, the radial flows are reversed, being outwards from the axis towards the outer wall. The flange 103 is a plate of insubstantial thickness so that the opposing radial flows are little separated and momentum exchange takes place through the gap around the periphery of the flange. The

heavier components of the mixture which in the region of the flange 103 are moving more slowly may, through this interchange of momentum, be given additional velocity so that instead of coming to rest on the bottom of the container 101 they may become re-entrained with the lighter components in the annular compartment and be carried together out of the container 101. It will be seen that the secondary flows are upwards in the middle of the container 101, tending to lift the denser components from their resting place in the bottom of the container 101. The separator is thus inefficient in that much of the initial separation of components has been reversed. Without a flange 103 at all, the secondary flow patterns would extend continuously between top and bottom of the container 101 and the denser components will almost certainly remain entrained with the lighter components.

When Figure 5 is contrasted with Figure 4, it will be seen that the axial extent of the flange 111 has been considerably increased, to a value at least as great as the radial extent of the gap 112. The flange 111 is no longer a thin plate, but is a large solid body whose axial extent is slightly greater than the radial extent of the gap 112 between the perimeter of the flange 111 and the outer wall of the cylindrical container 101. The reverse radial flows above and below the flange 111 are now well separated so that much less momentum exchange takes place across the gap and any tendency to reverse the separation of components is much reduced. The strength of the secondary flows is also reduced. There is less risk that a heavier component can escape upwards past the barrier through the gap 112. The efficiency of the separator is thus increased because separated heavier components are not re-entrained with the lighter components and more of them will come to rest at the bottom of the container 101. Good dust separation has been achieved with a 15mm gap between the baffle 124 and the sidewall of the container and an axial extent of the baffle rim of 20mm, a ratio of 4:3 baffle axial extent to

radial extent. Increasing the axial extent to 40mm, a ratio of 8:3, improves separation. Decreasing the gap to 10mm also improves performance, but also increases the risk of the gap becoming blocked by large particles. The best combination of good separation without blockages indicates the 4:3 ratio to be optimum.

If a large solid flange 111 is to be avoided for reasons such as economy in weight or cost, then a flange assembly comprising two separated plates 113a,113b may be provided, as shown in Figure 6. Although there may be a minor flow pattern established between the flanges 113a,113b, the chance of momentum exchange taking place across one flange and then again across the other flange to the same heavier component in the mixture is much reduced compared with the probability of exchange in Figure 4 and so the efficiency of separation is increased. The flange assembly may comprise more than two flange plates 113a,113b.

Figure 7 shows a flange assembly comprising two flange plates 114a,114b, the upper one of which is perforated. Although the flow pattern in the upper portion of the container 101 now extends to the region immediately above the lower flange plate 114b, the momentum is much reduced by passage through the perforations of the upper plate 114a, thus reducing the momentum exchange which occurs in Figure 4 where no such upper perforated flange plate 103 is provided.

It is not necessary for the flange plates to be plane discs. They may be provided with a partial or complete conical shape. Figure 8 shows an upper flange plate 115a of ogee shape and a lower flange plate 115b which is plane except for an outer rim which is a figure of revolution of a quarter-arc of a circle. The outer peripheries of the two plates 115a,115b are at approximately the same radial distance from the axis of the container 101 and the axial distance between the peripheral regions of the two plates

15a,15b is greater than the radial extent of the gap 112 between their peripheries and the outer wall of the cylindrical container 101. The flow patterns have not been illustrated in Figure 8, but will be similar to those in Figure 7 and the increase in efficiency compared to the arrangement of Figure 4 will be similar.

According to the invention there is provided a phase separator including an inlet chamber having an inlet, an outlet chamber having an outlet and an intermediate chamber forming a communicating passage between the inlet chamber and the outlet member such that fluid entering the inlet chamber is caused to swirl around the inlet chamber and move axially through the intermediate chamber to the outlet chamber where the heavier phases continue to swirl out through the outlet chamber, the outlet chamber having an axial outlet for lighter phases of the mixture, the outlet chamber being connected through means for retaining heavier phases therein to an axial inlet to the inlet chamber, which retaining means comprises a further cyclone separator stage having a collection chamber (herein referred to as a first collection chamber) for heavier phases, the arrangement being such that the collection chamber allows, in use, the formation of a vortex, the radial extent of which vortex is bound by the sidewalls of the collection chamber.

An involute shaped chamber preferably has a curved wall formed from at least three (and preferably four) arcuate portions of uniform curvature, each portion having a smaller curvature than the preceding inner portion, the adjacent portions having their centres on the common normal to the adjacent ends of those portions. An involute may have a maximum radius between 25% and 300% larger than the minimum radius.

The intermediate chamber may be frusto-conical, preferably with an outlet radius at least half the inlet radius, and

preferably with a length less than five times its inlet end diameter and more preferably less than its inlet end diameter.

The additional inlet in the upstream axial region of an involute chamber is very useful because the swirl imparted to the incoming mixture causes a low pressure in this axial region; the low pressure can therefore be used to draw in another fluid. The arrangement is very different from a jet pump, which normally has a low pressure inlet entering an axial chamber from one side and a high pressure inlet on the axis. In that case it is the axial high pressure inlet which causes a fluid to be drawn in from the side inlet. There is no effort made to induce swirl in such a jet pump.

The additional inlet should preferably be of a radius not greater than 50% (and more preferably not greater than 25%) of the minimum radius of the inlet involute and smaller than any outlet on the axis of the outlet involute. By passing through the retaining means only some rather than all of the full flow through the main separator, it is possible to use a retaining means of much smaller volume. Preferably all the fluid from said means of the outlet chamber is conducted to said retaining means.

The driving force for moving the fluid through the retaining means is provided by the low pressure existing at the additional inlet and so no additional energy is required; the driving force for moving the phase mixture through the separator as a whole may be in the form of a fan to draw the less dense fluid out of the separator. This has the advantage that the fan only has to deal with the lighter phases, whereas heavier phases might clog or damage it. Alternatively a pump may be provided to receive the fluid mixture before separation with its outlet connected to the fluid introducing means. A fan could be located between stages.

Preferably a baffle extends towards the outer wall of the container leaving a gap therebetween, the baffle having an outer perimeter which extends in the axial direction a distance not less than the radial extent of said gap. Since the outlet opens from said region, the flow of fluid from the fluid introducing means to the outlet is not obstructed by the baffle and does not pass through the gap.

The baffle may have a solid outer perimeter which is continuous in said axial direction; in a less preferred alternative the means may comprise a plurality of separated baffles spanning an axial distance not less than the radial extent of said gap. If the baffles are of different radial extents, the gap is measured to the baffle of largest radial extent. The baffle or baffles may be perforated. At least one of the baffles may be a curved or angled plate. We have found that baffle of or above this minimum axial extent provide efficient separation since little momentum exchange takes place across the baffle. In absolute terms the separator will only separate out particles which are smaller than the width of the gap.

When the second collection chamber is provided the baffle is preferably mounted on it. The walls of this second collection chamber preferably extend throughout said region and may extend throughout said container.

The lower portion of the container is preferably removable from the upper portion, so that it can be emptied of heavier phases in use. The container is preferably splitable between the portions about a plane below the baffle. When the second collection chamber is provided, the member is preferably splitable as well, and preferably about the same plane. The lower portions of the container and of the second collection chamber are preferably integral.

Axially extending additional baffle(s) may be provided,

sealed to said end of the container. The axial extent is preferably at least 10% of the diameter of the container at its closed end. The gap between the wall of the container and the or the outer baffle is preferably between 5% and 25% of the diameter of the container at its closed end.

The outlet of lighter phases of the mixture from the preliminary stage preferably comprises a foraminated screen leading to an annular chamber surrounding said second collection chamber. This screen is preferably frusto-conical, tapering outwardly in the downstream direction from the radius of said second collection chamber to which it is sealed at its narrow end. The axial length of the screen is preferably between 50% and 150% of the outer diameter of the annular outlet duct. The screen preferably has a clear area of between 30% and 70% of its surface area.

The present invention has particular applicability in domestic vacuum cleaners, where dust and other debris are separated from air, although phase separation of other materials including separation of two liquids is envisaged.

Example of the prior art and the invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a diagram of a three-stage phase separator of GB 2330786,
Figures 2 and 3 are transverse sections on respective lines 2 and 3,
Figure 4 shows secondary flow patterns in a conventional reverse flow cyclone provided with a barrier,
Figures 5 to 8 show secondary flow patterns in reverse flow cyclones,
Figure 9 shows a three-stage phase separator according to the present invention, and
Figure 10 shows fluid flow in the three-stage separator.

As illustrated in Figure 9, the third stage of the apparatus of the present embodiment differs from the prior art apparatus described above in that the frusto-conical chamber 73 in the third stage is omitted.

The prejudice in the art is that the frusto-conical chamber 73 will improve performance. The frusto-conical member 73 is thought to maintain the boundary layer and to maintain a proper flow of the heavier phase in a direction generally towards the base 33 and also is thought to reduce re-entrainment of heavier phase particles settled at the base 33.

However, the present inventors have found that the removal of the frusto-conical member 73 can actually improve overall performance of the apparatus. Removal of the frusto-conical cone leaves the interior volume of the inner cylinder 14 substantially uninterrupted. The absence of the frusto-conical chamber 73 gives the third stage a lower pressure drop, which increases flow through the third stage. This allows greater flow fluid to be drawn from the outlet 62 of the second stage to the inlet 71 of the third stage. The consequential increase in flow in the second stage increases the initial phase separation performance in the second stage and also the subsequent re-concentrating performance of carry over lighter phase from the third stage which returns to the second stage via inner cylinder 74.

According to the prejudice in the art, removal of the frusto-conical chamber 73 would cause dust settled at the base 33 to be re-entrained in the fluid swirling within inner cylinder 14. However, it has been found that a certain amount of heavier phase material is retained in the region adjacent to the walls of the inner cylinder 14 throughout the whole height of the inner cylinder 14. In effect, the sides of the inner cylinder 14 are coated with

heavier phase material and held in this region by the vortex. Material held in this way is not available for re-entrainment. Only a certain amount of heavier phase material can be held in this manner. However, it has been found that when the present apparatus is used in the context of a domestic vacuum cleaner, where the inner cylinder 14 is emptied after each use, the inner cylinder 14 will only vary rarely ever become more than 10% full of heavier phase material.

The third stage may optionally include a baffle 200 (Fig 10). The baffle 200 may be disc shaped or conical (as depicted in Fig 10). The baffle 200 is suspended on vertical member 202 which extends from the base 33. Between the outer periphery of the baffle 200 and the inner surface of the inner cylinder 14 an annular gap 204 is provided, which allows the passage of material past the baffle 200.

The vortex formed in the inner cylinder 14 has two components, a central forced vortex and, surrounding the force vortex, a free vortex. Without the baffle 200 present, the forced vortex will be free to extend from the upper region of the inner cylinder 14 to the base 33. If the forced vortex reaches the base 33 it may re-entrain heavier phase material which is settled on the base 33.

The presence of the baffle 200 acts to break the forced vortex and allows the forced vortex to attach to the baffle 200. This stabilises the vortex and allows heavier phase material such as fine dust to drop into the lower region of the inner cylinder 14 beneath the baffle 200. This will reduce re-entrainment which would be expected to occur if the vortex proceeded to the region of the base 33 of the inner cylinder 14.

The elimination of the frusto-conical chamber 73 allows significantly more flexibility in designing the apparatus.

The height of the third stage is largely dictated by the presence of the frusto-conical chamber 73. In order to allow heavier phase material collected at the base 33 of the inner cylinder 14 and in the annular collection chamber 31, the cylindrical container 12 splits at a level 34 and the inner cylinder 14 splits at a slightly lower level 35. This "break point" is indicated generally in Fig 10 by dashed line 206. For ease of use, so that the debris-containing parts of the cylinders 12, 14 can be easily removed for emptying, the frusto-conical chamber 73 must not extend below the break point 206. This dictates that the part of the inner cylinder 14 above the break point must be at least as long as the frusto-conical chamber 73. When the frusto-conical chamber 73 is removed this allows the length of the inner cylinder 14 and the outer cylinder 12 above the break point 206 to be significantly reduced in height. The overall size of the third stage can be significantly reduced whilst not compromising the capacity for debris collection in the removable part of the third stage.

CLAIMS

1. A phase separator including an inlet chamber having an inlet, an outlet chamber having an outlet and an intermediate chamber forming a communicating passage between the inlet chamber and the outlet member such that fluid entering the inlet chamber is caused to swirl around the inlet chamber and move axially through the intermediate chamber to the outlet chamber where the heavier phases continue to swirl out through the outlet chamber, the outlet chamber having an axial outlet for lighter phases of the mixture, the outlet chamber being connected through means for retaining heavier phases therein to an axial inlet to the inlet chamber, which retaining means comprises a further cyclone separator stage having a collection chamber (herein referred to as a first collection chamber) for heavier phases, the arrangement being such that the collection chamber allows, in use, the formation of a vortex, the radial extent of which vortex is bound by the sidewalls of the collection chamber.

2. A phase separator as claimed in claim 1 wherein a baffle is provided in said collection chamber for reducing re-entrainment of heavier phases settled in said collection chamber.

3. A phase separator as claimed in claim 1 wherein the involute of the inlet chamber inlet is an involute which extends in communication with the chamber around its full circumference.

4. A separator as claimed in claim 1 or claim 2 wherein the involute of the outlet chamber outlet is an involute which extends in communication with the chamber around its full circumference.

5. A phase separator as claimed in any one of claims 1 to 4 comprising a preliminary separation stage comprising

a separation chamber, means to introduce a fluid mixture into the chamber such as that it swirls around the axis of the chamber, a collection chamber (herein referred to as a second collection chamber) separated from the separation chamber by a baffle defining with the outer wall of the chamber a circumferential gap and a separation chamber outlet leading from the separation chamber, the separation chamber outlet being connected to said inlet chamber.

6. A separator as claimed in claim 4 and claim 5 wherein said first collection chamber comprises a cylinder extending within the chambers of the preliminary stage, said chambers of the preliminary stage being annular.

7. A separator as claimed in claim 6 wherein the first and second collection chambers are is separable from the separator chamber below the baffle.

8. A separator as claimed in claim 7 wherein the separable portions of the first and second collection chambers are integral with each other.

9. A separator as claimed in claim 5 or any claim dependent thereon wherein the outlet of the preliminary stage is connected to the separation chamber through a perforated frusto-conical shroud coaxial with the separation chamber.

10. A cyclone separator substantially as herein described with reference to and/or substantially as illustrated in Figs 9 and 10 of the accompanying drawings.

11. A vacuum cleaner including a phase separator as defined in any one of the preceding claims.

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19 -

Application No:	GB 0017382.3	**Examiner:**	Jason Scott
Claims searched:	1-11	**Date of search:**	17 January 2002

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: ONLINE: WPI, JAPIO, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2330786 A	B H R GROUP See whole document and in particular figure 1.	1, 2-9 & 11
A	US 4334986	AB CELLECO See whole document.	

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